A Clinical Interview for Assessing Student Learning in a University-Level Craft Technology Course

Victor R. Lee & Deborah A. Fields
Utah State University
2830 Old Main Hill
Logan, UT 84322-2830
+1-435-797-2694
{victor.lee; deborah.fields}@usu.edu

ABSTRACT

This paper describes the design and development of a clinical interview protocol, the "Interactive Toy Interview" (ITI), that was used to assess prior knowledge and resultant learning among undergraduate students enrolled in a new, university-level "Craft Technologies" course. This new course involved several weeks of project work with electronic textiles and soft circuits. The ITI draws on prior work assessing learning with e-textiles, such as circuit diagram drawing tasks and 'debuggems', but it is based on use of existing commercial toys and objects. We present excerpts from interviews with a student who reported no prior background with sewing, circuitry, or programing and discuss what kinds of progress we see in her thinking about interactive toys as they relate to experiences she had in the Craft Technology course.

Categories and Subject Descriptors

K.3.0 [Computers and Education]: General

General Terms

Human Factors.

Keywords

E-textiles, programming, assessment, clinical interview, LilyPad Arduino, soft circuits, computational crafts

1. INTRODUCTION

With the growing awareness of the Maker movement and the subsequent introduction of its tools, practices, and knowledge into learning spaces of all kinds (i.e., schools, libraries, museums, etc.) [7], educational technologists have great reason to be excited and optimistic. In many respects, some of the bold visions of democratic access to technologies for creation and personal expression are now one step closer to being realized [10,5]. We are now seeing learners of all ages, and all backgrounds, involved in the crafting and construction of new digital objects. The ability to design, create, and build computationally-enhanced interactive objects and devices is steadily moving to the masses [1].

However, we know fully well that there lurks an inevitable question waiting to be raised: What is it that people are learning when they 'make'?

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In order to answer the "inevitable question", we believe the field needs to develop methods suited to capture changes resulting from experiences with making. Describing one such method is the primary goal of this paper. The approach we describe involves a specially designed clinical interview, which we refer to as the "Interactive Toy Interview" (ITI). It was developed to help us ascertain what knowledge students enrolled in an university level course on craft and technology brought to bear before instruction and what knowledge they appeared to draw from after.

In the sections that follow, we will describe the university-level "Craft Technologies" course we examined. Of special note is that it heavily relied on electronic textiles (e-textiles) [2] as a primary exploration medium. We then discuss recent efforts to assess student learning with e-textiles and how those influenced our instrument design. We then overview our ITI protocol in terms of its design rationale, the materials we selected, and the question and task sequence we followed. Then, we present one example of pre- and post-responses from a student who was interviewed with the ITI protocol and discuss some of the observed changes in this student's thinking.

2. A CRAFT TECHNOLOGIES COURSE FEATURING ELECTRONIC TEXTILES

The course we focused on, entitled "Craft Technologies", was a brand new university-level semester-long course taught by the second author. The course was opened to both graduate and undergraduate students from any department in the associated university. Students from Art, Communications, Fashion and Education fields enrolled. The enrollment for the course was 20 (12 undergraduate students, 8 graduate students).

The Craft Technologies course was designed to engage non-science, non-computer science major students in a series of projects that would change the way they thought of and used computers and electronics. Over the semester, students completed a series of 5 semi-structured projects targeted to teach them techniques for using and understanding conductive materials (thread, fabric, yarn, wire, etc.), basic programming, human-computer interaction, and electrical properties (e.g. resistance, short circuits, polarity, etc.). Students also wrote reflective blog posts about the process of making each project: what went wrong, how they fixed things, what they learned, what they liked. The course culminated in a sixth and final creative project of each student's choice with an accompanying Instructables.com entry to provide detailed instructions and pictures about their final project to a broader audience online.

The course focused on e-textiles as a particularly promising entry point for women into computing and hardware [3, 12]. To this end the primary microcontroller used was the LilyPad Arduino, a sewable computer with inputs and outputs and an accompanying set of sensors (e.g. light sensors, accelerometers) and actuators (LEDs, sound buzzers, vibrator boards). Students also researched the properties of novel conductive craft materials like different conductive yarns, conductive threads, and conductive fabrics. They found ways to utilize these in conjunction with traditional (generally non-conductive) craft materials in order to create various sensors that could sense pressure, stretching, touching, etc. Thus the course introduced students to basic computing and circuit design as well as material properties.

3. ASSESSING LEARNING WITH E-TEXTILES

As noted above, e-textiles, particularly in the context of designed learning activities, are a rather new development. Much of the extant literature related to electronic textiles necessarily focuses on describing the associated technologies, discusses issues related to design of e-textiles instruction, and provides existence proofs for what students can make with electronic textiles given appropriate tools and support. As they are so new, there has so far been limited work to devise techniques for assessing student learning with e-textiles. The two exceptions involve some innovative work associated with using circuit diagrams as an assessment tool [11] and with using pre-designed challenge problems involving pre-planned mistakes, known as 'debuggems' [4].

The first approach, described in a recent study [11], involved assessment of knowledge related to electrical circuits before and after a 20-hour summer workshop on e-textiles with pre-adolescent youth at a local Boys and Girls Club chapter. After reviewing relevant circuit literature and considering the kinds of materials that the students would work with through the workshop, the researchers leading this study chose to design their assessment task – a diagram drawing activity – such that it drew upon familiarity with materials that students used most frequently during the summer workshop (e.g., LilyPad Arduino boards, LilyPad LEDs, etc). To reduce the overhead associated with reproducing electrical components by hand, they supplied each student a set of stickers that looked identical to LilyPad components. Using the drawn diagrams connecting these LilyPad stickers as a data source, the researchers were then able to devise a scoring rubric to evaluate knowledge change related to directionality of current flow, connections of wire and components, and polarity. Encouragingly, they found significant improvements in all areas.

The other approach used thus far to assess learning with e-textiles involved 'debuggems' [4]. Debuggems were isomorphic deconstruction kids that the researchers specially developed to embody a number of difficulties they saw students encounter when working with e-textile materials. Some of these difficulties are endemic to e-textiles as fabrication media. For example, short circuits are a unique problem with electronic textiles, as conductive thread is generally not insulated [8]. Loose or overlapping threads can easily come into contact with one another if a crafter is not meticulous about placing knots and planning where to stitch.

Like the drawn circuit diagrams, 'debuggems' were used to assess progress from a series of e-textiles workshops. Unlike the circuit diagram assessment, the assessment task involved an older population (high-school students) and was done in pairs over a set period of time. Subsequent evaluation of group performance on debuggem tasks showed that as a whole, students were able to solve all six pre-designed challenge tasks (ranging from short circuits to control flow), although no group of students were able to successfully find solutions for all the tasks in the time allotted (approximately one hour). The use of the debuggems was ultimately deemed promising, as the open structure of the task allowed researchers to ascertain the nature of collaboration during actual e-textile problem solving tasks and also identify common strategies or approaches students utilized as they unfolded in the process of debugging.

We view both of these assessment approaches as promising and with merit. Specifically, the circuit diagram assessment was appropriate considerate of immediate prior knowledge that could be embodied through some additional, researcher provided resources (i.e., LilyPad stickers), and the debuggems were especially useful for eliciting more open-ended data that could inform both future debuggem assessment tasks and also the design of specific e-textile challenge activities for use during instruction. With familiarity and interest in the design of these assessment tools in mind, however, we opted to design an alternate instrument. This instrument was intended to capitalize on some of the innovations introduced from circuit diagram and debuggem-style assessments, but were also tailored to some specific research interests associated with the current authors. Specifically, there was an interest in the current research collaboration to examine the broad range of knowledge that students bring with them prior to e-textiles instruction as well as ascertaining the degree of change that comes about after instruction. Thus, the assessment methodology was based in clinical interviewing, which has a track record of supporting researcher inquiries into both the breadth of prior knowledge and supporting documentation of knowledge change in response to designed instruction.

4. DESIGN OF THE INTERATIVE TOY INTERVIEW (ITI)

One of our main goals was to elicit relevant knowledge from both before and after classroom instruction. Given the newness of the technology and the course, we have found it necessary to devise new tasks tailored to the learning that we had hoped would take place in the context of a semester-long university course, which we describe below.

4.1 Anticipated Changes from the Course

In considering knowledge-related change for students enrolled in the Craft Technologies course, we identified two related areas interest. One was in the knowledge related to the use of the computational technologies and craft materials. Through their project work, students would encounter content related to circuits, sensors, computer programming, sewing, and crafting.

Additionally, we anticipated that not only would students be able to explain associated fabrication, computational, and craft content better (e.g., they would distinguish between different stitches or identify components in a logic board), but they would also be able to mobilize this knowledge to 'see' interactive objects differently. By this we mean that given simple interactive objects that light up, make noise, and respond to contact, students should be able to infer the kinds of components and configurations within the object that made that possible. We hoped that by spending time designing and completing soft circuits in a variety of tasks, they would be able to recognize and articulate some of the considerations that would have been made in the design and construction of an interactive object that was not of their own making. Moreover, we had hoped that they would also have appropriated new strategies into their repertoire if they were to be involved in some craft technology project of their own in the future, independent of the class.

Given these as targets, we deliberately sought everyday objects that students could ultimately 'see' differently or that could be feasible for students to 'make' on their own as a result of having taken the course.

4.2 Supporting Props for the ITI

The integration of high and low technologies has enabled development and explorations of interactive clothing, paper-based circuits that use copper tape or conductive ink, and decorative wall hangings that sense changes in the environment and respond accordingly. While we were very enthusiastic about the range of new high-low tech media and objects, our interest was in interactive objects that students enrolled in the course would have had previously encountered and would also likely encounter in the future. We ultimately settled on interactive objects that were already familiar to all and also congruous to the projects completed in the course: children's toys.

After visits to local toy stores and some informal tests of a variety of objects, we found three toys to use with a clinical interview. The first was a small, palm-sized plastic duck, distributed by *Toysmith*. Like other plastic ducks, this one was meant to float in water. However, this particular duck was built with electronic components such that when the duck was in water, three embedded LEDs would light up in a pre-programmed sequence for a set period of time. The sequence began when contact was made such that the two metal contact points underneath the duck were connected with some conductor and a circuit was completed. Thus, the duck would light up when placed in water, but it would also light up when metal objects or human skin completed the circuit.

Figure 1. The interactive duck.

The second toy was a stuffed rabbit modeled on the one from the children's book *Guess How Much I Love You* [9], produced by toymaker *Kids Preferred, LLC*. Meant for very young children (such as infants and toddlers), the rabbit was equipped with two LED lights and a small speaker. When the midsection of the rabbit, which was noticeably firm to the touch, was squeezed, the lights would flash and a brief song would play. Inside the rabbit were a series of insulated wires and two plastic cases. One plastic case housed a series of batteries. The other housed the speaker and an integrated circuit board connected to a small plastic button mechanism. The LEDs were located in each of the rabbit's ears. The music would come from the midsection. Both lights and song would terminate at the same time.

Figure 2. The interactive rabbit.

The third toy was a small plush elephant toy made by *Ty*, the company most commonly associated with "beanie babies" and other stuffed animals. This particular toy had no electronic components. Rather, we presented it in the ITI as an object that would need electronic components added to it. The plush elephant was selected for two reasons. First, we envisioned a reasoning task involving hypothetical placement of LEDs in the elephant's ears. Upon inspection of the elephant toy, the elephant was largely one single fabric casing (sewn from separate pieces of material). However, the ears were sewn on separately and were empty of any filling. They were not continuous with the rest of the elephant. Any effort to sew LEDs into the ears that connected to a controller anywhere else on the elephant's body would require some consideration of how to deal with the fact that the ears were separate pieces. Students who understood how toys were made would be able to demonstrate their sewing knowledge by noting the ears.

Figure 3. The non-interactive elephant.

Second, based on feel, the inner materials seemed potentially interesting for an interview. The main body and limbs contained a very soft and loosely packed fiber. The elephant would keep its shape vertically when held, but it lacked stiffness or rigidity, which could pose a challenge for soft circuits, where loose contact between conductive thread and components can break a circuit. Furthermore, there were a small number of beads located in the end of each foot. These provided rigidity and some weight, but the coarse and easily manipulated bead filling could pose additional challenges for any electronic interactivity that incorporated those areas. Thus, the interaction of soft material and circuitry could be explored well with this particular toy.

4.3 QUESTION AND TASK SEQUENCE

The interview consisted of three major tasks, with one associated with each toy. The general structure of the three tasks was the same: the interviewee was asked about some interactive capabilities associated, then asked what components or connections were involved, and then asked to draw a picture. The interviewees were informed at the beginning of the interview that they were welcome to handle any of the toys at any point in time.

While this was a common overarching structure and set of 'ground rules' for each task, we still designed each task with a particular line of questioning in mind. For the rubber duck, which was always introduced first, the researcher provided a small cup of water. The interviewer then placed the duck in the water where it floated and immediately lit up. The interviewee was then asked to explain why placing the duck in water led to it lighting up.

For the rabbit, the interviewee was given the rabbit and asked to squeeze its middle then describe what happened. After the ears lit up and the song played, the interviewee was asked to focus on the lights and explain why squeezing the rabbit led to the rabbit lighting up, although they were welcome to talk about the sound if they wished. Following a drawing of what they thought was inside the rabbit, they were also asked if the rabbit and the duck were triggered in similar or different ways and to explain why. In both cases, we knew that both toys involved completion of a circuit, and we wanted to see if this was a similarity that students recognized or if it the interface differences were such that the students considered the two to be markedly different.

With the elephant, the task presented to the student was to imagine that we wanted to make the plush toy interactive in the following way: upon touching both upper paws (the elephant's "hands"), both ears would light up. The ears would stay lit for as long as we were in contact with both paws. Contact with both paws would be required. This task was designed knowing that the course would cover both switches to complete circuits and capacitive touch sensors. There are many possible solutions tot his taskWe had hoped that students would bring knowledge related to either or both into their explanations. We also asked the interviewees to describe in detail the precise steps they would take, including any cutting, sewing, filling, or modifying they would do with the given plush toy.

5. DATA CORPUS

Even though the craft technology course was available to both undergraduate and graduate students, we used the ITI on just the undergraduate students, as they were all roughly around the same age. Eight volunteers met with one of two interviewers for a period of time ranging from 30 minutes to an hour during the week after the first class meeting. These same individuals met with the same interviewer during the last two weeks of the course, when they were responsible for completing and sharing final projects, but not covering newly introduced content. Seven of the original undergraduates participated in both pre- and post-interviews. All interviews were videorecorded. All drawings were collected and scanned.

6. SAMPLE PRE- AND POST- RESPONSES

To date, we are still early in the process of reviewing the rich data obtained from these interviews. Our current goal with this paper is to describe the interview instrument we had developed and illustrate, by way of excerpts from pre- and post-interviews with "McKell" (a pseudonym), the quality of data the ITI can produce.

6.1 McKell's Background

McKell reported having little to no prior experience with either sewing or circuitry. She was majoring in another department (Communications) and enrolled in the course to fulfill an elective requirement associated with a minor she was pursuing in multimedia development (which had historically emphasized courses related to using image editing or video editing tools). She had no prior computer programming experience. Informally, McKell reported to a member of the research team that this course seemed uniquely challenging to her as she felt she was the only person in the class without any prior craft or circuitry experience.

6.2 McKell and the Duck

During the pre-interview, McKell was immediately surprised that the duck lit up upon placement in the water cup. She then proceeded to consider a possible mechanism leading to the interactive behavior that variably relied on chemicals, sensors, and energy.

> McKell: Oh cool. It lights up once it hits the water?
> Int: My question is how does it do that?
> M: I'm assuming there is some type of chemical on the bottom that would, once water touches it gives it some sort of power.
> Int: What do you mean by a chemical in the product?
> M: I know how hand warmers have chemicals in it that warm it so maybe it's something like that. I don't know. [turns duck upside down] Maybe these sensors sense temperature or water making it work… once it hits water I assume that is what triggers the light up.
> Int: Does that involve chemicals too because you were just talking about it with the hand warmers?
> M: Yeah I think it would involve some type of chemical. Like something that mixed with water gives it energy.

Briefly, McKell began her explanation by attributing the activity to contact with "chemicals". She related this to other objects containing liquid that seem to generate some new behavior, such as chemically-activated handwarming pouches. Once she inspected the bottom and saw the contact points, she then immediately named those "sensors" and suggested they may respond to changes in temperature or contact with water. When the interviewer followed this line of questioning with a return to her mention of chemicals, she went back to talking about water being involved in some chemical reaction producing the behavior.

In seeing this transaction, it is critically important to avoid treating McKell's statements as reflecting some well-established, previously established mental model. Clinical interviews are known to produce explanations that are constructed by interviewees in the moment [13]. This is not to be seen as grounds for dismissing interviewee responses as being somehow tainted or otherwise unusable. Rather, McKell's comments can be seen as being the product of interactions between elements of prior knowledge that she feels is relevant to the task and the demands of the current interview situation. From McKell's initial response, circuits do not seem to be a consideration in her thinking. The water seems to be the trigger by virtue of it being water rather than a conductive medium.

During her post-interview, McKell drew on some of the same ideas as before, but her statements showed a number of changes.

Int: I have this rubber duck toy…[that lights up] My question for you is how does it do that thing [light up when placed in water]?
M: There is a sensor in the bottom so when it senses water, because water is conductive, I know that, so when it touches that the computer inside is programed so when it touches that to conduct it, it turns the lights inside. There are a few different lights inside that are connected to the computer probably as well so they are programmed to go in that sequence and then when the sequence is over it stops until you put it back again
…
Int: You said there was sensors [sic] and the water conducts. Explain what you mean by conductive.
M: Well you need something to activate it. [holds duck] Like my finger just activated it too because we have electricity in us and so does water, but wood doesn't. So if you put it on wood it doesn't do anything but you need something with some kind of little bit of electricity in it to make it start so that when it touches the metal it will complete the circuit.

In her post-interview response, McKell was far more confident and immediately talked about water being conductive and described some components likely to be inside the duck. She even proceeded to allude to some programming that would be involved. However, she still referred to the contact points as "sensors" and described them as being responsive to water rather than the circuit being completed by contact with water. When asked to elaborate, she talked about electricity being inside the conductive material.

This is not correct, and it bears some similarity to aspects of her pre- explanation. Retention and use of pre-instruction knowledge after instruction has been completed is often a hallmark of clinical interviews used to assess learning [13]. In fact, it can be a source of puzzlement and frustration since the 'correct' conceptualization was not fully reached. However, and as conceptual change researchers have stated before, knowledge change is a messy business. Even with high quality instruction and repeated instructional intervention, progress to a normative or expert-like understanding is incremental. However, this degree of change in this short of time, particularly for someone with no prior experience, is one we consider to be appropriate and a success.

6.3 McKell and the Rabbit

To illustrate McKell's performance on the rabbit task, we will simply focus on the drawings that she had produced. While McKell's speech and in-the-moment reasoning during the rabbit task are critically important for helping us best understand her thinking, we do want to illustrate, even in the limited confines of this short paper that is primarily about a data collection method, the kinds of drawings that students made.

As discussed earlier, circuit diagrams can be productively used to assess learning with e-textiles [11]. We believe that is seen with McKell. While the bulk of McKell's two drawings (Figure 4) looks much the same – both involve a rectangle, two knobs representing LEDs, and some lines connecting them – her thinking about circuits showed improvement as a result of the course. The most obvious change is in the use of two wires connecting the LEDs in the post when the pre only had one.

Through her inclusion of both positive and negative connections, McKell was demonstrating an improved awareness of how circuits must be completed and also an awareness of polarity. She also depicted a single ground (the long dashed lines) and two separate port connections. The two separate positive connections is worth noting because they could have shared a common connection, or the ears could have been connected to one another before reaching the positive port. The fact that she did not depict this is not a flaw in her reasoning. However, it does suggest that she was drawing very heavily from the models of light sequences she had covered in class, which typically involved LEDs connected to individual ports. Again, as this was all new material for her, we consider this to be a fine result.

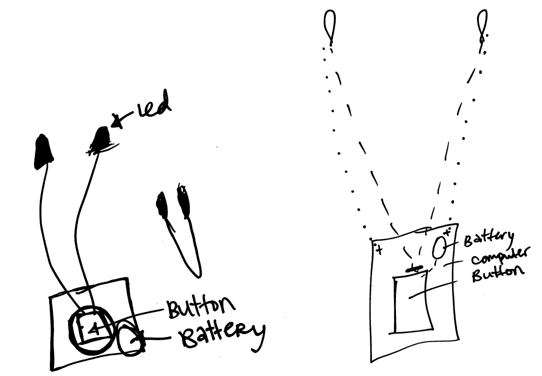

Figure 4: Pre- drawing (left) and Post- drawing (right) of the circuit design inside of the interactive rabbit.

6.4 McKell and the Elephant

For the elephant task in the pre-interview, McKell first drew on prior knowledge that she had explored during the duck and rabbit tasks that preceded. During that time, she had talked about sensors, wires, and batteries as all being necessary and also talked some about switches.

I: What sorts of materials do you think you would need to take the elephant and make it do that stuff? [light up when the paws are touched]
M: Probably either two buttons like in the rabbit or two sensors like in the duck. One on each paw. Then it would have wires to probably his middles. So the wires would connect together in the middle... They have to meet together so they have to talk.
Int: How do they talk?
M: When both thingy's sense, I'm sure when you push, if you push one in it would be 50% so nothing would happen. You would need both sides to work. So you would have to push both of them in to get the juice from this side plus the juice from that side to power this or else it won't have enough power probably. There is probably a battery there. Once it gets enough power from both sides it triggers the battery to work so then these would come up through the ears and they would have little LEDs. They would come together and mix and be shot out to light up those things.

Again, McKell's initial response draws on some relevant ideas, but was not technically correct. She generated an explanation that involved having a threshold of necessary power to work, something mixing, and light ultimately coming out of the ears. Her ability to describe in detail the steps she would take following this excerpt was, not surprisingly, limited. What was surprising in her post-interview was an added emphasis and commentary on more than a way to design the circuit. She also began to focus on and suggest strategies for improving the aesthetic of the elephant, as illustrated in the excerpt form her post-interview below.

Int: What types of material do you think I would need in order to make that happen?

M: I know people have done similar things like this in class. So you would need a LilyPad computer, you would need probably some type of metal sensor, some type of sensor on there, I just always use metal because it is easiest to conduct.
…
Int: Where would the LilyPad go?
M: You can put it just inside the belly….If you wanted to open him up but if you don't care about how he looks you could just put it on the outside too.
Int: What would you do if you were going to make this?
M: I don't really like the way the LilyPad looks so would probably put this on the inside. Maybe make a shirt for him too because you would see the stitching going through even if you put it on the inside you would see stitching if you put it on the inside of his belly on the outside. So you could make him a little shirt to cover it up. Or you could stitch it on to another piece of fabric probably and just throw it in there so you wouldn't have to stitch it on that.

In her response, McKell is more articulate and has a more viable plan for making the elephant ears light up. Beyond that, she also began to express opinions about how the elephant would look if a LilyPad were used. When asked what she would do herself if she were completing this elephant project, she recognized an issue immediately – that stitching the LilyPad inside the elephant would still result in some stitches being visible on the outside – and even proposed two novel solutions. One was to accept that, but then create a shirt to cover the stitching. The other was to put the LilyPad on a separate piece of fabric so that the outer fabric casing would not show any of the stitching. These were both good and viable solutions, and considering McKell did not have prior sewing experience, suggests she indeed learned more than how circuits work in the craft technology class. She also developed greater awareness of some best practices associated with the creation of fabric-based crafts.

7. DISCUSSION

McKell was just one student from a corpus of data that still awaits systematic analysis. However, if McKell is any indication, there were a number of ways in which students' knowledge showed some change as a result of their participation in the university level craft technologies class. The ITI protocol also appeared to be effective at revealing aspects of McKell's prior knowledge and subsequent knowledge change. Currently, we are making some progress on analyzing the entire corpus of interview data collected by the ITI. We are beginning to see the development of new actionable ideas related to circuitry, programming, and sewing for students who had limited prior knowledge in these areas.

In introducing the ITI protocol, we are not offering any specific critiques of existing assessment approaches, such as the circuit diagram drawing task or debuggems. Rather, we have attempted to present another tool that can be used to help us get closer to answering the "inevitable" question about what people learning through making. It is our hope that in preparing this paper, others may use the ITI or some variation of it in their own work. As it is a clinical interview, we believe the benefits of it as an assessment method are similar to those associated with clinical interviews generally: they can provide rich data about the breadth of knowledge that is drawn upon prior to and during instruction. It can also provide some needed flexibility for researchers who want to explore conceptual change as a product of making in education. In addition to data that have been collected about students' subjective experiences of the Craft Technologies course, we hope to provide more vivid images of the impact that a new, e-textiles centered course for non-science students can have.

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